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DRAWINGS ATTACHED

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(54) SMOOTH SURFACED OPEN FILAMENTARY MATERIAL

(71) We, MINNESOTA MINING AND MANUFACTURING COMPANY, a Corporation organised and existing under the laws of the State of Delaware, United States of America, of 2501 Hudson Road, Saint Paul, Minnesota 55101, United States of America, do hereby declare the invention for which we pray that a patent may be granted to us and the method by which it is to be performed to be particularly described in and by the following statement:—

This invention relates to filamentous materials and methods of making the same. More particularly, the invention relates to the preparation of smooth-surfaced open porous integrated matt (i.e. tangled mass) of continuous crinkled fibres or mono-filaments.

According to the invention a method of making such a matt comprises extruding a hot thermoplastic polymeric material in the form of a bundle of closely-spaced separate continuous filaments, permitting said filaments to fall under their own weight toward the surface of a liquid quench bath, maintaining a contact surface above said quench bath surface and in position to permit a glancing contact with at least a portion of the outer filaments of said bundle, and advancing the resulting bundle of filaments within said quench bath at a linear speed substantially less than the extrusion speed of said filaments, whereby to cause crinkling welding together and interengagement of said filaments into a lightly unified matt having a flat surface area of increased density.

Thus a smooth surfaced open filamentary article according to the invention comprises an open matt of interengaged continuous crinkled filaments of resilient thermoplastic polymeric material welded together at points of mutual contact to form an integrated structure at least a portion of one surface of which is flattened and contains a higher density of filament than does the inner portion of said matt.

An important field of utility for the products of the invention is in weather-resistant outdoor mats or carpeting. The smooth face of the web permits improved contact with the supporting surface and is particularly helpful in assuring good bonding with mastic or adhesive compositions applied thereto. The crush-resistant large-diameter crinkled filaments provide a safe, pleasant and wear-resistant walking surface. The extremely open nature of the web and the smooth surface of the filaments permits easy cleaning and washing as well as rapid drying. If desired, the matt may be further reinforced and strengthened by treatment with various resins or polymers applied from solution or suspension or in other ways; but the material as first formed has a surprisingly high degree of integrity permitting winding into rolls for storage, unwinding and handling for application, and subsequent treatment in use without disintegration.

The matt has also been found useful in the preparation of flexible molds for electrical cable splice areas and the like. A section of the matt is placed against an adhesive-coated non-porous flexible film, and the combination then folded about the splice area and sealed at the sides, in effect forming an open-top pouch which is then filled with suitable potting compound. The crush-resistant open matt holds the film at the desired distance from the cable while permitting the liquid compound to penetrate and fill the entire pouch and, after hardening, to encapsulate and insulate the splice area.

The invention will now be further described by way of example and with reference to the accompanying drawings in which:—

Figure 1 is a schematic illustration in elevation showing the process and apparatus used in making the matt;

Figures 2 and 3 are representations of front and back surface areas of a portion of a typical matt as made on the apparatus and by the method of Figure 1; and

Figure 4 is a representation of an edge

view of a segment of a matt having two opposing flattened surfaces.

As shown in Figure 1 the liquid fused polymer is extruded from a perforated nozzle or spinnerette head 10 as individual streams or filaments 11 which fall freely for a short distance before advancing into the quench bath 13. As the filaments enter the quench bath they cool and rigidify, thereby setting up a degree of resistance to the flow of the molten streams which as a consequence are caused to oscillate just above the bath surface. The resulting wavy motion establishes irregular periodic point contact between streams, causing spot welding of the filaments at those points. Some of the other filaments also come into contact with the smooth surface of the drum 12 and are thereby prevented from oscillation in that direction. The drum 12 rotates at a predetermined surface speed which is substantially lower than the rate of extrusion of the filaments. Thus the linear advancing speed of the matt is less than the extrusion speed. In general it is found that a ratio of advancing speed to extrusion speed of 2 to 7 is advantageous. The bundle of filaments is rapidly cooled and rigidified in the quench bath to form the integrated matt 14, which is then withdrawn from the bath and wound up on storage roll 15. The surface of the drum may be provided with spaced pins or pegs 16 or may be otherwise modified to assist in controlling the advance or modifying the structure of the matt 14 but is preferably generally smooth.

It will be seen that the surface of the drum 12 is wetted by immersion in the quench bath; but this is not essential, since stationary dry polished metal or other plates or the like have also been found to provide effective contact surfaces. Where danger of adhesion or otherwise induced sticking at the surface may be present, low-adhesion smooth coatings or films may be applied to the contact surface.

The amount of bonding or spot welding occurring during the process just described may be adjusted by changes in the particular polymer employed, the temperature of the filament at point of contact, the diameter of the filament, the rate of withdrawal of the matt, and in other ways. The additional number of contacts between filaments occasioned by contact with the smoothing plate or roll adds sufficient bonding to maintain adequate integrity and good handling characteristics in the matt while still permitting the removal of individual filaments in substantially continuous lengths without breakage.

The width and thickness of matt which may be produced by the technique just described is limited, e.g. by the size of extruder and number of orifices. As an example, a typical matt may contain a total of 260 filaments and have a width of eight inches and a thickness of 3/4 inch (1.9 cm.). In general however it has been found that matts can be made by the invention upwardly from one quarter of an inch thick. Fortunately it is found that the edges or faces of such webs may be joined together in a fully effective manner to produce webs of any desired width. The laterally extending coils and loops of the filaments along the adjacent surfaces intermesh sufficiently to produce a surprisingly effective bond when further treated with minimal quantities of hardenable liquid adhesive.

Usually the ratio of the average length of the contained filaments to the length of the matt is between 2 and 7.

The flattened surface portion of the matt contains a higher concentration or density of filament than does the remainder of the structure, and presents a greater contact area than does the opposite unflattened surface. As a result, adhesives are enabled to form a strong bond with the flattened surface. Preferably the ratio of fibre density at the flattened surface to that at a parallel plane removed from the flat surface is at least two. It is possible to flatten both surfaces, simply by including a second smooth-surfaced plate or drum in position for glancing contact with the other surface of the web of extruded soft filaments, where such modification is desired, while still retaining the open low density structure throughout the centre of the web. In another modification the filaments are extruded in a bundle having a generally circular or oval or other non-circular cross-section which is completely encircled by an annular contact plate to form a cylindrical structure having a continuous high-density smooth surface and a low-density interior.

The difference in surface density obtained between matt surfaces formed under free fall conditions and against a contact surface respectively is graphically illustrated in Figures 2 and 3, representing contact prints prepared by lightly touching the surface of the matt to a smoothly inked plate or roll and then lightly pressing the inked surface against a smooth white paper. The black lines 20 and 30 represent the inked surfaces of the filaments at the paper-contacting surface. Another method of measuring these surface differences involves a measurement of the gloss, i.e. the amount of light reflected at a given angle from the surface of the matt when illuminated from a standard source at the same angle. Typically, the reflection from the front surface is one-fourth to one-third the reflection from the more dense flat back surface.

As polymeric materials may be used polycarbonate, polyalkylene, polyester, polyvinyl, polyamide, ionomer and other resins which are extrudable at elevated temperatures in the form of soft flexible continuous filaments and which at lower temperatures have the required stiffness, toughness and other required physical and chemical characteristics. Particular

polymers may if desired contain plasticizers or softeners and may be otherwise modified by the addition of coloring agents, fibrous reinforcing agents, stabilizers, fillers and other additives. The completed matt may also be modified if desired, for example by treatment with solutions or suspensions of resins, bonding agents or coating agents as hereinbefore noted, or by dyeing or metallizing the filaments, or by further addition of particulate materials such as abrasive grains, metal flakes, fibrous flock, ground cork or the like, or by embossing, skiving, shearing, laminating, partial fusing or other physical treatment. An example is the introduction of a plastic screen or film at the contact surface which thereby becomes tightly bonded to the contacting layer of filaments to form a laminate structure.

Although filaments of very small as well as very large diameter may be produced and handled as herein described, products containing filaments within the range of approximately five mils (.125 mm.) to 125 mils (3.2 mm.), or preferably 15 to 35 mils (.4 to .9 mm.), in diameter, provide a high degree of resilience and crush resistance together with excellent mechanical strength and are preferred for uses requiring these properties, for example in outdoor carpeting and in cable molds as previously mentioned. Smaller and larger filaments behave similarly in many respects and may be used if desired, but diameters of less than about five mils (.125 mm.) make for difficulty in extrusion and lack of strength, whereas bundles or mats of rod-like fibers of very large diameter are stiff and difficult to handle and are useful only for specialized purposes.

The number and concentration of filaments is also subject to wide variation depending on the required matt density or porosity, thickness, and other properties. The thickness, for example as used in the calculation of void volume, is most satisfactorily determined by placing the matt on a flat surface, covering it with a sheet of light weight cardboard, and estimating the spacing between support and cover to the nearest millimeter.

The flat-surfaced, open, loosely bonded filamentary products of this invention have a number of fields of utility as hereinbefore noted wherein their resiliency, crush-resistance, low density, smooth filament surfaces and other properties combined with their improved surface characteristics offer important advantages. The products are also useful in the decorative field, and for such purposes may be produced in a variety of colors and in various patterns. As an example of the latter, the surface of the drum 12 may be suitably patterned, e.g. provided with cross-bars or other irregularities together with or in place of the pins 16; or a wave motion imparted to the surface of the quench bath may provide a wavy characteristic to the entire matt; or the rate of extrusion of the filaments may be periodically varied for a similar purpose, producing a periodic change in the apparent density or thickness of the matt.

Example 1

Polyester resin, prepared from ten parts of ethylene glycol, nine parts of terophthalic acid and one part of isophthalic acid and having a density of 1.334 gms./cc., is extruded under a pressure of approximately 500 psi (35 kg./sq.cm.) as required to obtain the desired rate of flow, through a spinneret 10 having 260 openings arranged in four rows of 65 openings each within a space of 5/8" × 8" (1.6 × 20 cm.) and positioned a distance of 8-3/4 inches (22 cm.) above the surface of a water quench bath 13 in an apparatus as indicated in Figure 1. The inner row of openings is arranged above the edge of a polished steel drum 12 having its axis at the water level and fitted with support pins 16, and which is driven at a surface speed of five feet per minute (2.5 cm./sec.). The polymer is extruded at a constant rate of 400 grams per minute but at different temperatures and through spinnerets of different orifice diameters as tabulated. The extruded streams begin to pursue a wavy or circular motion at about one inch (2½ cm.) above the surface of the quench bath, and the drum is set so that the outer streams first contact the drum surface at approximately that point. In the tabulation, O is the orifice diameter in inches (mm.); T is the temperature of the resin in degrees F. (degrees C.) just prior to extrusion; D is the diameter in inches (mm.) of the resulting filament as recovered from the matt; L is the average length in inches (cm.) of the continuous filament segments recovered from a two-inch (5 cm.) length of the matt; t is the thickness of the matt in inches (cm.); and V is the calculated void volume in percent of total measured volume using the nominal thickness determined as hereinbefore noted.

O	T	D	L	t	V
.031(.79)	490(254)	.026(.66)	5.0(12.7)	.63(1.6)	95.6
.031(.79)	500(260)	.024(.61)	7.3(18.6)	.63(1.6)	95.0
.031(.79)	510(266)	.020(.51)	9.8(24.8)	.63(1.6)	95.5
.024(.61)	490(254)	.081(.46)	6.5(16.5)	.69(1.8)	95.3
.024(.61)	500(260)	.018(.46)	6.8(17.3)	.69(1.8)	95.7
.024(.61)	510(266)	.016(.41)	7.8(19.8)	.69(1.8)	95.3

In each instance there is produced a unified, well bonded matt which is resistant to crushing under normal hand pressure. It is resilient and springy. The individual continuous filaments are bonded to each other at points of contact but may be broken away and removed intact. The back surface of the matt is flattened and is seen to contain a high concentration of filament, whereas the front surface is rough and irregular and is much more open.

EXAMPLE 2

The procedure of Example 1 is repeated using polycarbonate resin having a density of 1.26 and with the surface of the water quench bath positioned at a distance of six inches (15 cm.) beneath the spinneret. Rate of feed is 400 gm./min. and extrusion pressure is in the neighborhood of 800 psi (56 kg./sq.cm.).

O	T	D	L	t	V
.031(.79)	660(349)	.030(.76)	6.5(16.5)	.63(1.6)	93.6
.031(.79)	680(360)	.024(.61)	8.0(20.3)	.69(1.8)	93.6
.031(.79)	695(368)	.018(.46)	9.3(23.5)	.63(1.6)	93.5
.024(.61)	650(343)	.018(.46)	8.0(20.3)	.63(1.6)	90.7
.024(.61)	660(349)	.017(.43)	9.0(22.8)	—	—
.024(.61)	670(354)	.061(.41)	11.3(43.6)	—	—

The resulting product is generally similar to that of Example 1 but is somewhat more rigid.

EXAMPLE 3

Plasticized white pigmented polyvinyl chloride ("Geon 8814"; Geon is a Registered Trade Mark) having a density of 1.29 is processed as in the preceding Examples, except that the distance from spinneret to quench bath is six inches (15 cm.), and the take-up speed is 8 inches/min. (20 cm./min.). The extrusion pressure is less than 50 psi (3.5 kg./sq.cm.).

O	T	D	L	t	V
.031(.79)	380(193)	.035(.89)	4.5(11.4)	.50(1.3)	90.4
.031(.79)	390(199)	.022(.56)	11.8(30.0)	.50(1.3)	91.0
.031(.79)	400(204)	.020(.51)	10.8(27.5)	.63(1.6)	92.2
.024(.61)	380(193)	.018(.46)	7.0(17.8)	.80(2.0)	89.7
.024(.61)	390(199)	.017(.43)	8.5(21.5)	.63(1.6)	92.3
.024(.61)	400(204)	.017(.43)	8.0(20.3)	.63(1.6)	92.6
.016(.40)	380(193)	.016(.41)	7.0(17.8)	.50(1.3)	90.7
.016(.40)	390(199)	.016(.41)	7.8(19.7)	.38(1.0)	89.0
.016(.40)	400(204)	.015(.38)	5.5(13.9)	.38(1.0)	89.0

A red pigmented plasticized polyvinyl chloride ("Geon 8812") under the same conditions gives the following values:

.031(.79) 310(154) .022(.56) 10.8(27.5) .44(1.2) 89.0

When the vinyl resin is extruded directly into the quench bath without first contacting the drum, the strands contact and bond together to such a very limited extent that they come apart or separate into smaller groups or into separate strands under the gentlest handling and the matt cannot effectively be dried, wound up, or otherwise processed as a unit.

In a modified procedure a strip of thin, flexible, vinyl resin coated glass cloth, lightly pre-coated with liquid plasticizer for the vinyl resin, is introduced between the filaments and the rotating drum, which in this instance is free of pins 16. The filaments are lightly bonded to the cloth and to each other in a unified laminate.

The slight degree of bonding initially attained may be improved by subsequent treatment of the product with bonding resins, for example by adding a vinyl plastisol and heating. Similar treatment may be used to bond together two or more matts in either face-to-face or side-by-side position.

EXAMPLE 4

"Surlyn A—1601" ionomer (Surlyn is a Registered Trade Mark), having a density of .94 gm./cc., is extruded in the apparatus previously described, with a drop of 3½ inches (8.9 cm.) from spinneret to quench bath, at a rate of 180 grams/minute with matt recovery at 5 feet/minute (2.5 cm./sec.), using the .031 inch (.79 mm.) orifice and a melt temperature of 450°F. (232°C.), to produce a strong open crush-resistant matt which is flat and dense at the back surface.

The ionomer is a termoplastic tough copolymer of monomers of the type ethylene and methacrylic acid, and is particularly resistant to abrasion.

WHAT WE CLAIM IS:—

1. Method of making a smooth-surfaced open porous integrated articles of continuous crinkled filaments, which comprises extruding a hot thermoplastic polymeric material in the form of a bundle of closely-spaced separate continuous filaments, permitting said filaments to fall under their own weight toward the surface of a liquid quench bath, maintaining a contact surface above said quench bath surface and in position to permit a glancing contact with at least a portion of the outer filaments of said bundle, and advancing the resulting bundle of filaments within said quench bath at a linear speed substantially less than the extrusion speed of said filaments, whereby to cause crinkling, welding together and interengagement of said filaments into a lightly unified matt having a flat surface area of increased density.

2. Method of claim 1 wherein the ratio of advancing speed to extrusion speed is between 2 and 7.

3. Method of claim 1 wherein the polymeric material is extruded as filaments having a diameter between 5 and 125 mils.

4. Method of claim 3 wherein the polymeric material is extruded as filaments having a diameter between 15 and 35 mils.

5. A smooth-surfaced open filamentary article comprising an open matt of interengaged continuous crinkled filaments of resilient thermoplastic ploymeric material welded together at points of mutual contact to

form an integrated structure at least a portion of one surface of which is flattened and contains a higher density of filament than does the inner portion of said matt.

6. The article of claim 5 wherein the filaments have a diameter of between 5 and 125 mils.

7. The article of claim 6 wherein the filaments have a diameter of between 15 and 35 mils.

8. The article of claim 5 wherein the ratio of the average length of the contained filaments to the length of the matt is between 2 and 7.

9. The article of claim 5 wherein the ratio of the fiber density at the flat surface to that at a parallel plane removed from the flat surface is at least two.

10. The article of claim 5 having a thickness of at least one-quarter inch (.6 cm.).

11. The article of claim 5 having two opposing flattened faces.

12. A method of making a smooth-surfaced open porous article substantially as herein described.

13. An article made by the method of any one of claims 1—4 or 12.

14. A smooth-surfaced open filamentary web substantially as herein described.

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1247373 COMPLETE SPECIFICATION
1 SHEET *This drawing is a reproduction of the Original on a reduced scale*

FIG. 1

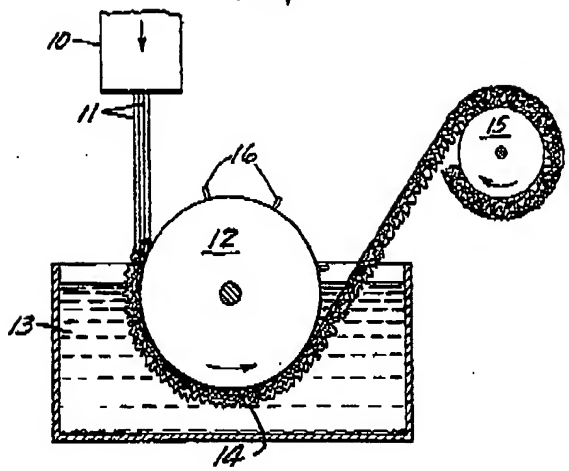

FIG. 2

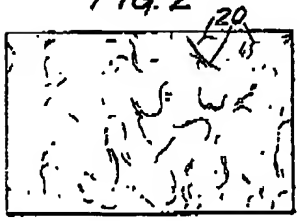

FIG. 3

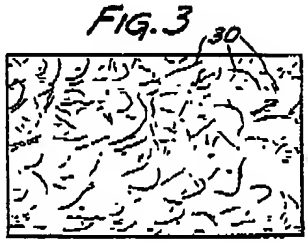

FIG. 4